Fringe 2015 Workshop

Sentinel-1 TOPS data coregistration

operational and practical considerations

ESA ESRIN, Frascati, Italy
March 23, 2015

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Agenda

- Algorithmic review: How to handle TOPS
  - Spectra management
  - Bursts Management
  - Coregistration, coregistration, coregistration
- Stack processing considerations
- TOPS InSAR open issues
TOPS InSAR

It's all about knowing how to answer these technical challenges:

- Doppler Sweep
- Burst Mode
TOPS InSAR

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- Doppler Sweep → use Spotlight algorithms
- Burst Mode → how to coregister
It's all about knowing how to answer these technical challenges:

- Doppler Sweep → use Spotlight algorithms
- Burst Mode → how to coregister
  → when to stitch
  → how to stitch
  → what can be corrected by exploiting the small burst overlap

...and how to interpret TOPS InSAR signals
1400 x 250km coherent interferogram
Lessons Learned (TOPS context)

“Looking Back to Look Forward”

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Envisat BAM ScanSAR interferogram

Notice beautiful azimuth misregistration fringes!
“SAR processing is an integration/summing process, and in which order you sum a collection of samples does NOT matter!”
Analogy between Spot and TOPS

Spectral equivalence of Spotlight and TOPS modes

“...if one knows how to form Spotlight interferogram, it can easily leverage that experience in computation of per-burst TOPS interferograms”
Deramping: Real Data Example
Deramping: Real Data Example
Bursted nature of TOPS data

“The TOPS is a wide swath mode that has the same coverage and resolution as of the ScanSAR mode, but without scalloping effect”
Bursted nature of TOPS data
Brief theoretical intermezzo:

**Sensitivity of InSAR phase on coreg errors**

\[
\phi_{az\_err}(r, t) = 2\pi f_{DC}(r, t) \Delta t
\]

\[
\phi_{rg\_err}(r, t) = \frac{4\pi}{\lambda} \Delta r \left[ 1 - \sqrt{1 - \left( \frac{\lambda f_{DC}(r, t)}{2v} \right)^2} \right]
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Effect of misregistration

Case study:

- Simulated strike slip quake, 2m slip
- Effect of constant offset 0.05 pixels

*Figure credit A.Hooper*
TOPS InSAR: It's all about coregistration

High level flow diagram for coreg strategy

Highlights:
- Geometric approach
- Reliable initial orbits assumed
- Utilization of burst overlap phase
- Flexible: designed for overall coreg but can also be down-scaled to a single burst level
Coregistration Dissection [1/2]

Initial Coregistration:

*Use available geo/orbit/metadata for the initial coreg*

Refinements:

- **First Refinement:**
  
  *Use m/s offset from 'traditional' coregistration to model orbit errors, while still following a geometric approach.*

- **Second Refinement:**
  
  *Apply the spectral diversity method on burst overlaps to estimate residual azimuth registration error.*

  Note: Range errors not significant by SD can be also applied on range.
Coregistration Dissection [2/2]

Registration/Resampling of full image:

- Twice refined geometry
- Moderate Topography: SAR geometry should be sufficiently good, only small/negligible phase errors
- Rough Topography: DEM info needed, depending on the baseline.

Correction of residual Az coreg errors:

- Residual coreg Az error → phase difference between bursts
- Geometric approach → this difference is a single number
For Geometric Strategy to Work:

• Assumption #1: Orbit Quality
  • Master orbit is error free:
    • State vectors within 10cm
    • Satellite velocity and direction very high precision
    • Absolute positioning errors on 10cm level not important

• Assumption #2: Source of Residual Coreg Error
  • After correcting for geometry difference between m/s residual coreg error is due to:
    • constant azimuth timing error
    • constant radial error of the slave orbit

Assumption 1 & 2 → Coregistration problem reduced to geometric approach
Innovative nature of 'our' coregistration

Geometric approach
- From start to end
- State vectors should be and are good enough
- Problem reduced
- A single azimuth timing error and single radial error for whole product
- Overall coreg, not only where coherent

Exploitation of 'view angle diversity' (i.e., redundancy) in burst and swath overlap zones
- Overlaps opportunity to model and mitigate az coreg errors
Overlap Zones: An opportunity

Sketch of a geometry of two-looks on a target in the burst overlap zone
Overlap Zones: An opportunity

Phase of overlap zone in case of 'stationary-scene'
Overlap Zones: Non-Stationary Scene

Phase of overlap zone in case of 'non-stationary-scene': Lambert Glacier
Summary

• We have a very good understanding of single interferogram processing scenario
  • Geometric approach necessary to ensure consistent quality regardless of data
  • Use overlap zones for residual azimuth coregistration

• Challenges:
  • Quantification of necessary amount of data to use for coregistration
  • 'Non-Stationary' scenarios
  • Orbit reliability ← quite good!
  • Coregistration via time-series of burst overlaps